Artificial Intelligence in Undergraduate Medical Education: A Scoping Review

Juehea Lee, Annie Siyu Wu, David Li, and Kulamakan (Mahan) Kulasegaram, PhD

Abstract

Purpose
Artificial intelligence (AI) is a rapidly growing phenomenon poised to instigate large-scale changes in medicine. However, medical education has not kept pace with the rapid advancements of AI. Despite several calls to action, the adoption of teaching on AI in undergraduate medical education (UME) has been limited. This scoping review aims to identify gaps and key themes in the peer-reviewed literature on AI training in UME.

Method
The scoping review was informed by Arksey and O’Malley’s methodology. Seven electronic databases including MEDLINE and EMBASE were searched for articles discussing the inclusion of AI in UME between January 2000 and July 2020. A total of 4,299 articles were independently screened by 3 co-investigators and 22 full-text articles were included. Data were extracted using a standardized checklist. Themes were identified using iterative thematic analysis.

Results
The literature addressed: (1) a need for an AI curriculum in UME, (2) recommendations for AI curricular content including machine learning literacy and AI ethics, (3) suggestions for curriculum delivery, (4) an emphasis on cultivating “uniquely human skills” such as empathy in response to AI-driven changes, and (5) challenges with introducing an AI curriculum in UME. However, there was considerable heterogeneity and poor consensus across studies regarding AI curricular content and delivery.

Conclusions
Despite the large volume of literature, there is little consensus on what and how to teach AI in UME. Further research is needed to address these discrepancies and create a standardized framework of competencies that can facilitate greater adoption and implementation of a standardized AI curriculum in UME.

Over the past decade, artificial intelligence (AI) has advanced rapidly due to an ever-increasing amount of data and computing power.¹ AI is the capability of a machine to imitate cognitive tasks such as image recognition, speech recognition, and caption generation.² Simply put, AI models can be used to find patterns in large quantities of data to make highly accurate predictions for various tasks.³ In medicine, AI is on the precipice of instigating large-scale changes that will transform how health care is delivered, the tools used by health care professionals, and the traditional roles of patients and health care professionals.⁴,⁵ The accuracy of machine learning algorithms has reached or exceeded that of expert physicians on numerous tasks. For example, an AI system surpassed human radiologists in breast cancer prediction and outperformed the average radiologist by an absolute margin of 11.5%.⁶ Another AI system could identify 26 common skin conditions representing 80% of cases seen in primary care with performance noninferior compared with dermatologists and superior to primary care physicians and nurse practitioners.⁷ New emerging technologies raise numerous questions about the future of medicine and the role of human physicians. Despite increasing interest in new technology, medical education has not kept pace with the remarkable breakthroughs made in AI. There have been several calls to action,⁸⁻¹⁰ but adoption of AI training into undergraduate medical education (UME) has been limited, perhaps due to the lack of systematic evidence.¹¹ As adoption of AI continues to grow in health care, integration in UME will offer substantial benefits for future practice since UME can reach the largest group of medical trainees early in their careers. An understanding of how AI should be taught and integrated into UME curricula should be guided by the best available scholarly evidence. Since AI is still a relatively new concept in medical education, a synthesis of the literature is required to determine where the evidence is and what gaps remain.

As such, the objective of this scoping review was to map key themes and identify gaps in the available literature on how best to train and prepare undergraduate students for clinical practice in the age of AI. The results of this study will inform current practices and highlight future areas of scholarship for the medical education community.

Method
Scoping reviews aim to address a broad or exploratory research question through a comprehensive review of the literature.¹²,¹³ This scoping review focuses on the topic of AI training in UME. We chose to use a scoping review as this topic is complex and has not been reviewed comprehensively before.¹⁴ To ensure that our methods were reliable and could be easily replicated, we followed the methodological framework proposed by Arksey and O’Malley and Levac and colleagues.¹²,¹³

Please see the end of this article for information about the authors.

Correspondence should be addressed to Juehea Lee; email: juehea.lee@mail.utoronto.ca.

First published online August 3, 2021
doi: 10.1097/ACM.0000000000004291
Copyright © 2021 by the Association of American Medical Colleges
Supplemental digital content for this article is available at http://links.lww.com/ACADMED/B156.
Identifying the research question

The primary research question of this scoping review was: “What key themes and gaps can be identified in the existing literature on AI training in UME?” Specifically, the purpose of this scoping review was to summarize and disseminate key themes regarding AI training in UME in the current literature as well as identify potential research and scholarly priorities to advance AI curricular development in UME. 13 To meet this objective, we defined AI broadly, including subdomains of AI such as machine learning, deep learning, and natural language processing, to expansively search the available literature. In contrast, we restricted the scope of this review to UME only. We anticipated that AI training at the graduate or postgraduate level may be specialty-specific and focus on concepts or applications that are not applicable to all medical learners. By focusing on UME, we sought to identify concepts on medical AI education that could lay the groundwork for all medical learners.

Identifying relevant studies

Our search strategy, created with the help of a medical librarian, consisted of medical subject headings, keywords, and text words related to AI and its subdomains (e.g., machine learning) as well as to UME (e.g., clinical clerkship, medical student, medical learner). The initial search was conducted on November 25, 2019, in 7 electronic databases, including Medline, Embase, PubMed, Scopus, ERIC, MedEdPortal, and Cochrane Library. The search was updated on July 21, 2020. The search was limited to English publications from January 1, 2000, and onward. We chose to restrict the search by publication date and language due to the rapidly evolving nature of AI and limited access to translational services, respectively. The search was supplemented by hand-searching reference lists of included articles. The full version of the search strategy can be found in Supplemental Digital Appendix 1 at http://links.lww.com/ACADMED/B156.

Study selection

All citations were imported and managed using the Covidence online software (Veritas Health Innovation, Melbourne, Australia). Study selection was performed in 3 steps. First, 3 reviewers (J.L., A.S.W., D.L.) independently screened titles and abstracts to determine study eligibility. All studies that discussed AI training in UME were included. Second, following initial title and abstract screening, we discussed and refined the inclusion and exclusion criteria post hoc. Third, we performed full-text screening using the inclusion and exclusion criteria. Conflicts were resolved through discussion and consensus at each stage.

Overall, articles were included in the review if they broadly discussed AI training in UME. Articles were excluded if they:

1. Focused exclusively on the teaching of AI in postgraduate or continuing medical education;
2. Focused exclusively on the teaching of AI in osteopathic medicine or for allied health professionals;
3. Explored the use of AI as a tool for medical education as opposed to a topic within medical education curricula; or
4. Were a conference abstract or where a full-text manuscript was not available. No other restrictions were implemented for publication type or methodology.

Charting the data

Data extraction occurred through an iterative process. First, data charting was performed using a structured form (see Supplemental Digital Appendix 2 at http://links.lww.com/ACADMED/B156). Three reviewers (J.L., A.S.W., D.L.) extracted data from all full-text articles using the data charting form. We then met to ensure consistency between forms, resolve disagreements, and refine the form based on increased familiarity with the literature. Upon discussion, we decided to further divide the results extraction column into the following categories: why (e.g., Why should AI be taught to undergraduate medical students? What are the learning objectives?), what (e.g., What should be taught to medical students about AI?), how (e.g., Who would the instructors be?), how (e.g., How should an AI curriculum be delivered to medical students?), where (e.g., In what setting should an AI curriculum be delivered?), and how well (e.g., What steps were taken to determine the effectiveness of AI curriculum?). The division of these categories was informed by the guideline for Reporting Evidence-based practice Educational interventions and Teaching (GREET), 15 a validated checklist developed for the reporting of educational interventions for evidence-based practice, to help organize data extraction. Using the updated data extraction form, 3 reviewers (J.L., A.S.W., D.L.) re-reviewed and extracted data from all full-text articles. This process was repeated until consensus was reached.

Collating, summarizing, and reporting the results

Study demographics were summarized using descriptive statistics. Qualitative data from the extraction form were grouped into emerging themes using thematic analysis, informed by Miles and Huberman’s methodology, as follows. 16 First, we assigned descriptive codes to identify patterns and common topics within each full-text article. We performed a second cycle of coding to generate pattern codes that grouped multiple descriptive codes into a smaller number of categories or themes. Next, we created matrices summarizing each article according to the categories identified in the previous step. The matrices were then reduced into a single table, where commonalities and differences between articles were visualized and noted. We finally reframed the categories into curricular recommendations to help inform educational reform for AI in UME (see Figure 1).

Results

Study characteristics

Our search identified 4,299 unique titles, of which 22 full-text articles were included in our final analysis. 8–11,17–34 The majority of these articles were perspective pieces (n = 18, 81.8%), with 3 papers authored or coauthored by the same author, Steven A. Wartman (see Table 1). Other study designs include reviews (n = 2, 9.1%), a case study (n = 1, 4.5%), and a keynote speech (n = 1, 4.5%). While many articles originated from the United States (n = 9, 40.9%), there was a diverse representation of study settings, including Canada (n = 4, 18.2%), South Korea (n = 2, 9.1%), France (n = 1, 4.5%), India (n = 1, 4.5%), the Netherlands (n = 1, 4.5%), New Zealand (n = 1, 4.5%), Oman (n = 1, 4.5%), Pakistan (n = 1, 4.5%), and Spain (n = 1, 4.5%) (see Table 1). Here we present the key themes derived from our scoping review.
Why should medical students be taught it? How will AI affect the practice of medicine?

All 22 studies identified the inevitable impact of AI on health care and the need for medical education to adapt and integrate AI.8–11,17–34 Most studies discussed the imminent impact of diagnostic and predictive AI tools on physicians' decision-making processes,18,20,21,24,28,29,33 citing AI systems that outperform physicians in interpreting medical images.17,19–21,24,25,31,32 Furthermore, authors agreed that while current AI systems can only perform highly specific, pattern-based tasks,17,19–21,24 AI would soon expand to impact physicians' decision-making processes more broadly. For example, some posited that AI systems will complement physicians' decision-making processes.

Figure 1 Adapted Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram. Abbreviations: AI, artificial intelligence; UME, undergraduate medical education.
responsibility to nurture students’ academic interests in AI.

What will medical students need to know to work alongside AI systems?

Numerous studies discussed the overall learning goals of AI in UME—a clinically focused curriculum providing students with a conceptual understanding of AI in clinical practice. However, limited studies addressed specific AI learning objectives and curricular recommendations. Similarly, while governing organizations such as the American Medical Association made calls to integrate AI in UME, they did not provide specific curricular recommendations. Nevertheless, we present 5 key AI learning objectives common to several papers (see Table 2).

Working with and managing AI systems. Most studies discussed the need for UME curricula to teach students skills needed to work with and manage AI in clinical practice. This included fostering students’ understanding of foundational statistical concepts critical to comprehending AI approaches; understanding AI fundamentals; including concepts like machine learning and natural language processing; appreciation for the application, benefit, limitations, and risks of AI systems; ability to operate AI systems, that is, the ability to provide meaningful input to AI so that AI systems can capture, process, and apply the data to its algorithms; (5) appreciation for the impact of AI on clinical reasoning; and (6) ability to meaningfully communicate AI results (often probabilities) to patients.

Ethical and legal implications of AI systems. Ten authors discussed specific learning objectives related to understanding AI systems’ ethical and legal implications. This was considered essential in ensuring safe and informed use of AI systems. Specific learning objectives include (1) providing students with frameworks to approach AI ethics and (2) facilitating discussions of important AI ethics topics like liability and data privacy.

Critical appraisal of AI systems. Eight studies discussed equipping students with skills to critically appraise AI systems. This included fostering students’ understanding of critical appraisal and evidence-based medicine to evaluate and assess the hype versus reality of AI tools and their claims.

Continued emphasis on biomedical knowledge and pathophysiology of disease. Four authors addressed the need to continue emphasizing students’ biomedical knowledge, in contrast to 3 authors who argued otherwise. Lynn explained this as an essential learning objective, at least in the next few decades where novel AI tools are created and implemented. Physicians will play a critical role in evaluating the claims made by novel AI tools, and biomedical knowledge of diseases is essential to appraise these newly developed AI systems.

Working with electronic health records. Electronic health records (EHRs) are the primary mode of data collection for AI systems. Thus, 4 authors argued the need for medical curricula to provide students with knowledge of EHR design principles and skills to communicate and provide unbiased input to EHR (which will then be used by AI systems to inform its algorithms).

What will medical students and future clinicians need to know to meet new roles created by changing practice paradigms as driven by emerging AI technologies?

Thirteen out of 22 studies discussed additional non-AI competencies physicians must foster in response to the AI-driven health care changes. This was regarded as a natural evolution of physicians’ roles in response to AI and a necessary step to avoid being replaced by AI. Specifically,
### Table 2

**Key Artificial Intelligence (AI) Curricular Recommendations**

<table>
<thead>
<tr>
<th>AI curriculum objectives</th>
<th>Studies</th>
<th>Subthemes</th>
</tr>
</thead>
</table>
| Working with and managing AI systems | 8-11,17-24,26-34 | Foundational statistical concepts critical to understanding AI tools  
- Foster students understanding of foundational statistical and medical informatic concepts—data aggregation, analysis, and personalization.  
- Foster students understanding of foundational statistical and medical informatic concepts—data aggregation, analysis, and personalization.  
- Foster students understanding of foundational statistical and medical informatic concepts—data aggregation, analysis, and personalization.  
- Foster students understanding of foundational statistical and medical informatic concepts—data aggregation, analysis, and personalization. |
| AI fundamentals needed to understand and use AI tools | 8-11,17-24,26-34 |  
- Foster students’ understanding of AI fundamentals, including machine learning; natural language processing; and basic pipeline of data acquisition, cleaning, analysis, and visualization.  
- Foster students understanding of foundational statistical and medical informatic concepts—data aggregation, analysis, and personalization.  
- Foster students understanding of foundational statistical and medical informatic concepts—data aggregation, analysis, and personalization.  
- Foster students understanding of foundational statistical and medical informatic concepts—data aggregation, analysis, and personalization. |
| Operating AI systems | 8-11,17-24,26-34 |  
- Help students learn how to inform and communicate with AI to receive meaningful results and to engage in appropriate handoffs with AI tools, e.g., how to use data mining tools, how to engage in verbal and written communication with AI, the role of voice input.  
- Help students learn how to inform and communicate with AI to receive meaningful results and to engage in appropriate handoffs with AI tools, e.g., how to use data mining tools, how to engage in verbal and written communication with AI, the role of voice input.  
- Help students learn how to inform and communicate with AI to receive meaningful results and to engage in appropriate handoffs with AI tools, e.g., how to use data mining tools, how to engage in verbal and written communication with AI, the role of voice input.  
- Help students learn how to inform and communicate with AI to receive meaningful results and to engage in appropriate handoffs with AI tools, e.g., how to use data mining tools, how to engage in verbal and written communication with AI, the role of voice input. |
| Impact of AI on clinical reasoning | 8-11,17-24,26-34 |  
- Foster students’ understanding of the strengths and weaknesses of different AI systems.  
- Foster students’ understanding of the strengths and weaknesses of different AI systems.  
- Foster students’ understanding of the strengths and weaknesses of different AI systems.  
- Foster students’ understanding of the strengths and weaknesses of different AI systems. |
| Communicating AI results to patients | 8-11,17-24,26-34 |  
- Help students learn how to inform and communicate with AI to receive meaningful results and to engage in appropriate handoffs with AI tools, e.g., how to use data mining tools, how to engage in verbal and written communication with AI, the role of voice input.  
- Help students learn how to inform and communicate with AI to receive meaningful results and to engage in appropriate handoffs with AI tools, e.g., how to use data mining tools, how to engage in verbal and written communication with AI, the role of voice input.  
- Help students learn how to inform and communicate with AI to receive meaningful results and to engage in appropriate handoffs with AI tools, e.g., how to use data mining tools, how to engage in verbal and written communication with AI, the role of voice input.  
- Help students learn how to inform and communicate with AI to receive meaningful results and to engage in appropriate handoffs with AI tools, e.g., how to use data mining tools, how to engage in verbal and written communication with AI, the role of voice input. |
| Ethical and legal implications of AI systems | 8-11,17-24,26-34 | Ethical and legal implications of AI tools in clinical practice  
- Consider applying medical informatic ethics to medical AI ethics as guiding principles.  
- Provide frameworks to approach AI ethics at clinical and systems levels.  
- Familiarize students with AI ethics at clinical and systems levels.  |
| Continued emphasis on biomedical knowledge and pathophysiology of disease | 8-11,17-24,26-34 | Continued emphasis on the acquisition of biomedical knowledge and pathophysiology of disease  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems. |
| Critical appraisal of AI systems | 8-11,17-24,26-34 | Critical appraisal of AI systems to ensure safe and effective integration and utilization in clinical practice  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems. |
| Working with electronic health records | 8-11,17-24,26-34 | Communicating and understanding electronic health records (EHRs) and their role in AI systems  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems.  
- Foster students understanding of the strengths and weaknesses of different AI systems. |
Uniquely, Masters\textsuperscript{16} and Pinnock et al\textsuperscript{23} discussed how even empathy may not be the sole role of physicians, as AI systems could replace it. Nevertheless, both authors emphasized the need for physicians to be taught improved communication and counseling skills to communicate more effectively and empathically with patients.\textsuperscript{19,21}

How should an AI curriculum be delivered?

Three studies\textsuperscript{11,23,27} discussed the delivery of AI curricula. However, there was no clear consensus on how best to deliver an AI curriculum in UME. The delivery recommendations were broad (i.e., not specific to learning objectives—except for McCoy et al\textsuperscript{27}) and not based on a particular education theory. Table 3 includes a list of medical schools with pilot AI curricula.

Nevertheless, all 3 studies\textsuperscript{11,23,27} highlighted the importance of experiential learning, that is, providing opportunities for students to work directly with AI tools. Two out of 22 studies\textsuperscript{11,27} discussed using small-group sessions and lectures as a means to teach AI fundamentals. McCoy et al\textsuperscript{27} and Paranjape et al\textsuperscript{23} highlighted the utility of e-modules and interactive case-based workshops to teach students AI fundamentals and cultivate their understanding of AI ethics, respectively.

Two studies\textsuperscript{11,23} discussed the possibility of embedding AI content into preexisting curricula focused on information technology (e.g., evidence-based medicine) and discussed potential instructors for AI curricula, such as interdisciplinary instructors.\textsuperscript{11,23}

What are the challenges associated with introducing an AI curriculum into UME?

Six studies\textsuperscript{8–11,23} highlighted the challenges associated with introducing AI curricula. Studies discussed faculty resistance, lack of AI accreditation and licensing (e.g., USMLE) requirements, and limited curricular hours as barriers to introducing AI curricula in UME.\textsuperscript{8–11,23} Additional barriers include lack of AI core competencies,\textsuperscript{18} lack of faculty expertise on AI,\textsuperscript{11,23} and lack of evidence regarding how AI will impact health care delivery.\textsuperscript{23} Methodological comments on the literature

All 22 articles included in this review identified a need to prepare medical students for the integration of AI into medicine and put forth recommendations for an AI curriculum. While common themes emerged, inconsistencies between recommendations were noted. For example, authors such as Johnston,\textsuperscript{17} Li et al,\textsuperscript{24} and Wartman\textsuperscript{8} suggested that AI will replace clinicians as medical experts. As such, they argued that medical schools should de-emphasize basic sciences and dedicate increased curricular hours for the “nonanalytical, humanistic” aspects of medicine, such as communication skills. In contrast, authors such as de Leon,\textsuperscript{25} Lynn,\textsuperscript{26} Srivastava and Waghmare,\textsuperscript{22} and Park et al\textsuperscript{26} argued for continued prioritization of basic sciences and pathophysiology to work with and maintain appropriate oversight of AI tools.

While all 22 articles presented numerous curricular recommendations, only 3 out of 22 articles discussed delivery of an AI curriculum.\textsuperscript{11,23,27} 1 out of 22 articles discussed methods of evaluation,\textsuperscript{22} and no articles discussed learning outcomes.

Finally, we noted a poor representation of study types in the available literature on AI training in UME. Eighteen out of 22 articles were perspective.

Table 3

Medical Schools With Pilot Artificial Intelligence (AI) Curricula

<table>
<thead>
<tr>
<th>Medical school</th>
<th>Description of AI curriculum</th>
<th>Author (year)\textsuperscript{ef}</th>
</tr>
</thead>
<tbody>
<tr>
<td>University of Toronto</td>
<td>- Preclinical lectures (Intro to Machine Learning in Healthcare, AI, Medicine, and the Future of Doctoring) &lt;br&gt; - 2-year Computing for Medicine certificate program &lt;br&gt; - AI in medicine interest group</td>
<td>McCoy et al (2020)\textsuperscript{27}</td>
</tr>
<tr>
<td>Harvard Medical School</td>
<td>- Clinical informatics elective &lt;br&gt; - Collaborative Data Science in Medicine course &lt;br&gt; - Datathons</td>
<td>McCoy et al (2020)\textsuperscript{27}</td>
</tr>
<tr>
<td>University of Texas (Dell Medical School)</td>
<td>Curriculum in basic sciences has been reduced to 12 months to accommodate training in soft skills such as leadership, creativity, and communication through group problem solving while deemphasizing memorization</td>
<td>Paranjape et al (2019)\textsuperscript{25}, Johnston (2018)\textsuperscript{26}</td>
</tr>
<tr>
<td>Duke Institute for Health Innovation</td>
<td>Medical students work together with data experts to develop care-enhanced technologies made for physicians</td>
<td>Paranjape et al (2019)\textsuperscript{23}</td>
</tr>
<tr>
<td>University of Florida</td>
<td>Radiology residents work with a technology-based company to develop computer-aided detection for mammography</td>
<td>Paranjape et al (2019)\textsuperscript{25}</td>
</tr>
<tr>
<td>Carle Illinois College of Medicine</td>
<td>Offers a course by a scientist, clinical scientist, and engineer to learn about new technologies</td>
<td>Paranjape et al (2019)\textsuperscript{25}</td>
</tr>
<tr>
<td>Sharon Lund Medical Intelligence and Innovation Institute</td>
<td>Organizes a summer course on all new technologies in health care, open to medical students</td>
<td>Paranjape et al (2019)\textsuperscript{25}</td>
</tr>
<tr>
<td>Standard University Center for Artificial Intelligence in Medicine and Imaging</td>
<td>Involves graduate and postgraduate students in solving health care problems with the use of machine learning</td>
<td>Paranjape et al (2019)\textsuperscript{23}</td>
</tr>
<tr>
<td>University of Virginia Center for Engineering in Medicine</td>
<td>Involves medical students in the engineering labs to create innovative ideas in health care</td>
<td>Paranjape et al (2019)\textsuperscript{23}</td>
</tr>
<tr>
<td>University of Ulsan</td>
<td>AI-dedicated elective courses</td>
<td>Park et al (2019)\textsuperscript{26}</td>
</tr>
<tr>
<td>Yonsei University</td>
<td>AI-dedicated elective courses</td>
<td>Park et al (2019)\textsuperscript{26}</td>
</tr>
</tbody>
</table>
Discussion

This scoping review summarizes the currently available literature regarding AI training in UME, mapping key themes and highlighting gaps in the literature that can inform current practice and future research.

All included articles were published between 2017 and 2020, reflecting the budding interest in AI among the medical education community. All included studies discussed their rationale for introducing AI curricula in UME, including the impact of AI in health care delivery. Likewise, all studies included suggestions for AI curricular content and from it, we derived 5 key AI themes that medical educators should consider when developing AI curricula (see Table 2). However, there was considerable heterogeneity across studies and a lack of consensus regarding which AI skills students should learn during UME. Each article emphasized one or more elements of AI learning domains, with no single study discussing all 5 themes.

Similarly, 3 out of 22 of studies discussed AI curricula delivery. Various pedagogical approaches were suggested, including lectures, e-modules, and small-group learning, in line with the diverse AI skill sets. Common to all authors' recommendations was experiential learning—providing students with the opportunity to work directly with AI tools. However, none of the studies explicitly discussed educational theories or frameworks that informed their AI delivery recommendations, and very few papers included case studies of implemented programs. Among the few case studies of piloted programs, none reported on outcomes of their AI curriculum, such as student satisfaction, knowledge acquisition, and skill transfer. Due to the lack of evaluations and the heterogeneity among AI curriculum delivery recommendations, we could not extrapolate a consensus regarding how best to deliver AI curricula.

Numerous factors may have contributed to the lack of consensus regarding AI curricular content and delivery: (1) lack of AI integration efforts due to the barriers identified from studies included in this scoping review, (2) AI is a relatively new field with remarkable advances made within the last 10 years—medical educators may not simply had enough time to appreciate how AI will impact health care delivery and thus medical education, and (3) the complexity of integrating AI curricula—working in AI-integrated health care requires complex skill sets that include AI-specific competencies along with improvements in non-AI domains such as skills of caring (i.e., empathy and communication).

Thus, in light of the highlighted gaps in the literature, we propose 3 next steps that medical educators should take in their efforts to deliver AI curricula in UME.

1. Create a standardized set of core competencies for AI training

Core competencies are a combination of attributes like knowledge and skills that enable an individual to perform a set of tasks to an appropriate standard. Thus, a set of competencies developed using consensus-group methods such as nominal group technique or Delphi surveys will offer a shared language that addresses the inconsistency in literature, provides a framework for developing AI educational curricula, and informs advocacy efforts to organizations such as the Canadian Medical Association for the inclusion of AI skills in accreditation and licensing requirements.

2. Develop and implement flexible, evidence- and theory-informed AI curriculum with purposeful and planned evaluations to refine and improve the curriculum in response to feedback

This scoping review highlights the paucity of literature regarding the delivery of AI curriculum in UME. However, the vast medical education literature regarding best practices can guide the development of evidence- and theory-informed AI curriculum. One suggestion is an AI curricular delivery informed by Steiner et al. comprising (1) diverse education methods to teach diverse AI skills sets (e.g., lecture/modules to teach AI fundamentals versus discussion-based tutorials for nuanced conversations regarding AI ethics) and (2) experiential learning—providing students with the opportunity to work with AI tools and receive feedback regarding their AI skills. Ultimately, like other foundational and preparatory knowledge domains, AI training needs effective integration at the program, course, and session levels. Integration of AI appropriately with teaching on clinical reasoning and other core activities may increase the efficacy of such teaching and limit overcrowding or “bloating” current UGME curricula.

Furthermore, we postulate that the key to creating an AI curriculum is not about creating the perfect curriculum. Instead, it is about developing a flexible and evidence-informed curriculum with purposeful and planned evaluations to facilitate iterative refinements to the curriculum in response to student and faculty feedback. Evaluations of AI curriculum can include self-reported changes in students’ attitudes, objective measures of AI knowledge, and longitudinal outcomes such as acquisition of new AI relevant skills in future training.

3. Increased effort to publish findings regarding AI curricular content and delivery to disseminate, contribute to, and extend the literature on AI and UME

Our scoping review identified a lack of literature regarding curricular content, delivery, and in particular, the evaluation of AI training in UME. We advocate for increased research and commitment among medical educators to share and publish available findings to guide and advance AI curricular development in UME.

Limitations

Our findings should be interpreted in the context of its limitations. We only included studies written in English and did not examine gray literature, that
AI has the potential to have significant and wide-sweeping impacts on medicine. Medical education must prepare learners for these potential changes. UME has a potentially unique role in AI training and medicine as it (1) allows for early exposure and integration of AI into medical education and (2) has the capability to reach the broadest medical learner population. While this scoping review identified important considerations for AI curricular content and delivery, significant heterogeneity and poor consensus within the literature was also identified. Further research will be needed to appraise and reconcile this evidence to adequately prepare medical learners for the forthcoming integration of AI in medicine.

Acknowledgments: The authors wish to thank Dr. Lisa Freeman, Dr. Janet Corral, Dr. Caitlin Gillian, Dr. David Wiljer, and Dr. Marcus Law for their valuable insight and feedback. They would also like to thank the incredible medical librarian team at Gerstein Science Information Centre for their support.

Funding/Support: None reported.

Other disclosures: None reported.

Ethical approval: Reported as not applicable.


References

37. Albarqouni L, Hoffmann T, Straus S, et al. Core competencies in evidence-based...


